(19) Europäisch s Patentamt
European Pat nt Office
Offi européen d s br vets

(11) EP 0 620 570 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
12.02.1997 Bulletin 1997/07

(51) Int Cl.[6]: **H01F 6/06**, H02H 9/02

(21) Application number: **94302178.2**

(22) Date of filing: **25.03.1994**

(54) **Superconducting fault current limiter**

Supraleitende Anordnung zur Fehlerstrombegrenzung

Dispositif supraconducteur pour limiter le courant de défaut

(84) Designated Contracting States:
CH DE LI

(30) Priority: **26.03.1993 JP 68758/93**
11.05.1993 JP 109585/93
15.06.1993 JP 144004/93
21.06.1993 JP 149589/93
26.11.1993 JP 297032/93

(43) Date of publication of application:
19.10.1994 Bulletin 1994/42

(73) Proprietor: **NGK INSULATORS, LTD.**
Nagoya City Aichi Pref. (JP)

(72) Inventors:
- **Yoshida, Shinji, Gurandouru-Inuyama 101-go Inuyama-shi, Aichi-ken, 484 (JP)**
- **Motoyama, Shuichiro, NGK Komaki-ryo Komaki-shi, Aichi-ken, 485 (JP)**
- **Ohashi, Takashi Kasugai-shi, aichi-ken, 486 (JP)**
- **Ishihara, Masamichi Ama-gun, Aichi-ken (JP)**

(74) Representative: **Paget, Hugh Charles Edward et al**
MEWBURN ELLIS
York House
23 Kingsway
London WC2B 6HP (GB)

(56) References cited:
EP-A- 0 353 449
FR-A- 2 661 288
FR-A- 2 677 503
US-A- 4 894 360
WO-A-90/02407
FR-A- 2 666 912
US-A- 3 443 255

- **PATENT ABSTRACTS OF JAPAN vol. 13, no. 401 (E-816) (3749) 6 September 1989 & JP-A-01 144 602 (HITACHI CABLE LTD)**

EP 0 620 570 B1

Printed by Jouve, 75001 PARIS (FR)

Description

The present invention relates to a superconducting fault current limiter, more particularly to a fault current limiter utilizing the superconductivity of a ceramic high-temperature superconductor the superconducting state of which is switched to a resistive state when a fault current beyond a critical value is applied.

In recent years, there has been proposed an inductive current limiter for protection of a circuit breaker or a transformer in power networks from fault currents caused by a short-circuit or thunderbolt. When a fault current occurs, the inductive current limiter provides a high impedance which limits the fault current to restrain an electric load acting on the circuit breaker and transformer below a threshold level. In US-A-5,140,290, there is disclosed a high power inductive current limiter of this kind which is composed of an induction coil with at least one winding through which current flows, a cylindrical body made of a ceramic high-temperature superconducting material concentrically arranged within the induction coil, and a core made of a soft magnetic material of high permeability concentrically disposed within the cylindrical body. In normal operation, the superconductivity of the cylindrical body shields the magnetic field of the induction coil completely from the core (Meissner effect), and impedance of the induction coil is maintained at a very low level to minimize loss of the electric power. When a fault current flows through the induction coil due to a short-circuit or thunderbolt, the superconductivity of the cylindrical body disappears and the impedance of the induction coil reaches its maximum, current-limiting value. FR-A-2 666 912 discloses a similar device.

To maintain the superconductivity of the cylindrical body in normal operation , the inductive current limiter is immersed in cooling liquid such as liquid nitrogen. In the conventional inductive current limiter, however, the cylindrical superconductive body is surrounded by the induction coil and is in contact with the cooling liquid only at its inner peripheral surface. For this reason, the cooling efficiency of the superconductive body becomes insufficient, particularly in the case that the superconductive body is large in thickness. Furthermore, the superconductive body is greatly affected by eddy current losses in the iron core and joule losses caused by the resistance of the induction coil since it is disposed between the iron core and the inductive coil, resulting in a decrease of the critical value of the fault current limiter.

Since the conventional fault current limiter is entirely immersed in the cooling liquid to cool the superconductive body, the cooling device becomes large in size. In actual use of the fault current limiter, the induction coil is heated by its self-resistance when applied with transport current, and the iron core is also heated by the flow of eddy current caused by a magnetic field acting thereon after transition to the resistive state. As a result, the cooling liquid is heated by heat generation of the induction coil and iron core. If the cooling liquid boils due to the heat generation, there will occur an excessive increase in volume of the cooling liquid, resulting rapid increase of the internal pressure of the cooling device. To avoid such a problem, it is required to provide a pressure release mechanism on the cooling device. This results in a complicated construction of the cooling device and an increase of the manufacturing cost.

Additionally, the self-resistance of the iron core becomes small when the iron core is cooled. This causes an increase of the eddy current in the iron core after transition to the resistive state. Thus, the magnetic field in the iron core is reduced by the eddy current, and the relative permeability of the iron core becomes small. Accordingly, the iron core does not serve to increase the self-conductance of the induction coil after transition to the resistive state.

It is, therefore, required in commercial applications of the fault current limiter to enhance the cooling performance of the cooling device in a reliable manner and to provide the cooling device in a small size at a low cost.

JP-A-1-144602 discloses a method of reducing the heat load on a liquid helium cooled superconducting magnet coil, by placing a nitrogen jacket around it.

A primary object of the present invention is to provide an improved fault current limiter capable of at least partly satisfying the requirements described above.

According to the present invention, there is provided a superconducting fault current limiter, comprising an induction coil (4) connected in series with an electric power transport line, said coil being arranged in surrounding relationship with a core (3) made of a high resistance magnetic material, said core being carried by a support structure (1) forming a closed magnetic circuit; a superconductive body (5) arranged adjacent to and co-axial with said coil, said superconductive body being made of a ceramic high-temperature superconducting material; and a cooling device (20) arranged to cool said superconducting body; characterised in that said superconducting body (5) surrounds said coil (4) at the outside thereof.

The superconducting fault current limiter may further include a cooling device arranged to cool only the superconductive body. In a practical embodiment of the present invention, it is preferable that the superconductive body is in the form of a cylindrical superconductive body coaxial with the induction coil or a coiled superconductive body coaxial with the induction coil.

The cooling device may comprise a cylindrical cooling container containing only the cylindrical superconductive body therein and filled with cooling liquid to immerse the superconductive body therein.

An impedanc el ment such as a resistor, a condenser or a coil may be connected in parallel with the induction coil to restrain the flow of current passing through the induction coil on the occurrence of a short-circuit or thunderbolt.

In a practical embodiment of the present invention, it is pref rable that the induction coil is arranged in surrounding relationship with a core made of a high resistance magnetic material such as ferrit , wherein the core is carried by a support structur forming a closed magnetic circuit, and it is also preferable that a heat insulating material is disposed between the induction coil and the superconductive body to avoid fluctuation or decrease of the critical current value of the fault current limiter casued by joule heat of the induction coil.

For a better understanding of the present invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Fig. 1 is a perspective view of a superconducting fault current limiter in accordance with the present invention;
Fig. 2 is a graph showing a relationship between a value of current flowing through an induction coil shown in Fig. 1 and the inductance of the induction coil;
Fig. 3 is a perspective view of a coiled superconductive body to be replaced with a cylindrical superconductive body shown in Fig. 1;
Fig. 4 is a sectional view of a cooling container adapted to the fault current limiter shown in Fig. 1;
Fig. 5 is a list showing a consumption amount of liquid nitrogen in the cooling container shown in Fig. 4 in contrast with a conventional fault current limiter;
Fig. 6 is a diagram of a test circuit for the fault current limiter shown in Fig. 1;
Fig. 7 is a sectional view of a modification of the fault current limiter shown in Fig. 1; and
Fig. 8 is a diagram of a test circuit for the modified fault current limiter shown in Fig. 7.

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, in Fig. 1 there is illustrated a superconducting fault current limiter 10 having a core structure 1 composed of a pair of spaced solid support bodies 2, 2 and a pair of vertically spaced solid columnar bodies 3, 3 which are made of soft magnetic material such as soft iron. The columnar bodies 3 each are dimensioned to be 38mm in diameter and 60mm in length and detachably connected to the respective support bodies 2 by means of fastening screws (not shown) to provide a closed magnetic circuit. The upper columnar body 3 is surrounded by an induction coil 4 which is connected in series with an electric power transport line. The induction coil 4 is in the form of an enamel winding wound around the columnar body 3 with 120 turns in one layer.

The fault current limiter 10 includes a cylindrical superconductive body 5 arranged in surrounding relationship with the induction coil 4. The cylindrical superconductive body 5 is made of a ceramic high-temperature superconducting material such as bismuth type superconducting material and dimensioned to be 40mm in its inside diameter, 50mm in its outside diameter and 50mm in its length. Thus, the inner peripheral surface area of superconductive body 5 is determined to be about 6280mm^2, while the outer peripheral surface area of superconductive body 5 is determined to be about 7850mm^2. In addition, the superconductive body 5 surrounds the induction coil 4 with a slight clearance without being supported from the exterior.

In this embodiment, the material of superconductive body 5 was selected from the group consisting of Bi-Sr-Ca-Cu-O, where particles of Bi_2O_3, CuO, $SrCO_3$ were prepared in a mixing ratio of Bi:Sr:Ca:Cu = 2:2:1:2. The critical current density (Jc) of the superconductive body 5 was determined to be 1000A/cm^2 in a critical magnetic field (Bc) of 0.005T (50 gauss). The fault current limiter 10 is immersed in cooling liquid such as liquid nitrogen stored in a cooling vessel 6. When the rated current is applied in normal operation, the cylindrical superconductive body 5 in surrounding relationship with the induction coil 4 is maintained in the superconducting state and shields the magnetic field of the induction coil 4 completely from the iron core in the form of the upper columnar body 3. Thus, the inductance of the induction coil 4 is maintained very low to permit the flow of rated current passing therethrough without any limitation. When the induction coil 4 is applied with a fault current due to a short-circuit or thunderbolt, the superconductive body 5 turns resistive from the superconducting state to provide a high impedance which limits the fault current.

In such a construction of the fault current limiter 10 as described above, the superconductive body 5 is exposed to the liquid nitrogen at its outer peripheral surface the area of which is larger than that of its inner peripheral surface. As is understood from the foregoing calculation, the outer peripheral surface area of the superconductive body 5 is larger by 1600mm^2 (about 25.5 %) than the inner peripheral surface. On the other hand, the induction coil 4 is located inside the superconductive body 5 and constantly exposed to the liquid nitrogen. Thus, the cooling efficiency of the liquid nitrogen is enhanced to increase the critical value of the fault current limiter 10. Although in the conventional fault current limiter, there has been a difficulty in replacement of the superconductive body due to the outside arrangement of the induction coil, the superconductive body 5 of the fault current limiter 10 can be replaced with a fresh one in a simple manner by removal from the support bodies 2. Since the induction coil 4 is not wound around the superconductive body 5 as in the conventional fault current limiter, the mechanical stress acting on the superconductive body 5 is avoided.

In Fig. 2 there is illustrated a current-inductanc characteristic of the fault current limiter 10. In the graph of Fig. 2, the inductance of the whole circuit is represented by a y-axis, a current value is represented by an x-axis, and measured

values ar represented by characters A-G. As a result of the measurement, it has been confirmed that the current across th induction coil 4 r aches a critical curr nt value at 6 to 7 ampere. Th measurement values fluctuated in accordance with a critical magnetic field of the induction coil 4 and a critical temp rature of the superconductive body 5. In addition, the critical value of the fault current limiter 10 varied in inverse proportion to the number of windings of the induction coil, and the inductance of induction coil 4 varied in proportion to the square of the number of windings of the induction coil 4.

In a practical embodiment of the present invention, the fault current limiter 10 may be modified as described below.

1) The cylindrical superconductive body 5 may be integrally formed at its opposite ends with a pair of axially spaced annular flanges.
2) As shown in Fig. 3, the cylindrical superconductive body 5 may be replaced with a coiled superconductive body 15 formed to be arranged in surrounding relationship with the induction coil 4. In use of the coiled superconductive body 15, it is possible to smoothly discharge nitrogen gases appearing at the outer periphery of the induction coil 4.
3) Liquid helium may be used as the cooling liquid in use of a superconducting body made of NbTi type superconducting substance.
4) The superconductive body 5 may be changed in thickness. In the case that the superconductive boy 5 is enlarged in thickness to increase a difference of its inner peripheral surface area and its outer peripheral surface area, the cooling efficiency of the liquid nitrogen is more enhanced. In addition, the induction coil 4 itself may be in the form of a superconducting wire.
5) The superconductive body 5 may be snugly coupled with the induction coil 4 to avoid leakage of the magnetic flux so as to decrease loss of the transport current in normal operation.
6) The superconductive body 5 may be constructed in the form of annular multi-layered thin plates.
7) The bismuth type superconducting substance of the cylindrical superconductive body 5 may be prepared by an appropriate mixing ratio other than Bi:Sr:Ca:Cu = 2:2:1:2 and also substituted by yttrium type superconducting substance.

In Fig. 4 there is schematically illustrated a cooling device 20 adapted to cool the cylindrical superconductive body 5 of the fault current limiter 10 shown in Fig. 1. The cooling device 20 is in the form of a double walled cylindrical container formed to contain therein only the cylindrical superconductive body 5 and is arranged in surrounding relationship with the induction coil 4 wound around the soft iron core 3. The cylindrical container 20 has an internal cylindrical wall 21 surrounded by an external cylindrical wall 22 and formed integrally therewith at its one end to form an annular cavity 23. The annular cavity 23 is closed by an annular end plate 24 secured to opening ends of the cylindrical walls 21, 22 and is filled with liquid nitrogen. The double walled cylindrical container 20 is made of stainless metal or titanium alloy and is provided with inlet and outlet ports through which the liquid nitrogen is supplied into the annular cavity 23 and discharged therefrom. The cylindrical superconductive body 5 is entirely immersed in the liquid nitrogen stored in the annular cavity 23 of container 20.

In application of the cooling container 20 to the fault current limiter 10, only the superconductive body 5 is immersed in the liquid nitrogen filled in the cooling container 20, while the iron core 3 and induction coil 4 are exposed to the atmospheric air. Accordingly, the cooling container 20 can be formed in a small size, and the amount of liquid nitrogen can be reduced. Since the liquid nitrogen is not directly affected by heat generation of the induction coil 4 in normal operation, the cooling efficiency of the fault current limiter 10 can be enhanced at a low cost. Furthermore, the cooling container 20 can be adapted to the fault current limiter 10 without providing any pressure release mechanism since the heat generation of the induction coil 4 does not vaporize the liquid nitrogen. This is useful to simplify the construction of the cooling container 20. In addition, the relative permeability of the iron core 3 is maintained without any influence caused by the liquid nitrogen to provide sufficient current limiting effects after transition to the resistive state. In this embodiment, it has been confirmed that the relative permeability of the iron core is maintained at a value of about 5.0 after transition to the resistive state.

Since in this embodiment the liquid nitrogen does not act to cool the iron core 3, there will not occur any decrease of the resistance of the iron core. This results in a decrease of the eddy current flowing through the iron core after transition to the resistive state. Accordingly, the eddy current to the magnetic flux in the iron core becomes small, and the relative permeability of the iron core becomes large in contrast with that in the conventional fault current limiter. Thus, the provision of the iron core is effective to increase the self-inductance of the induction coil 4 after transition to the resistive state so as to enhance the current limiting ability of the fault current limiter.

In the table of Fig. 5, a consumption amount or vaporized amount of the liquid nitrogen before and after transition to the resistive state of the fault current limiter 10 are listed in contrast with those in the conventional fault current limiter. In this measurement, the transition or critical current value from the superconducting state to the resistive state has been determined to be 7 A. When current of 3 A flows through the induction coil 4, both the current limiters are maintain d in the superconducting state, respectively. When current of 10 A flows through the induction coil 4, both the fault

current limiters ar switched over from the superconducting state to th resistive state. As shown in the table of Fig. 5, the consumption amount of liquid nitrogen in the conventional current limiter was 60g/min before trasition to the resistive state and 180 g/min after transition to th resistiv state. In contrast with the conventional fault current limiter, the consumption amount of liquid nitrogen in the fault current limiter 10 of the present invention was 30 g/min before transition to the resistive state and 50 g/min after transition to resistive state. As is understood from the above measurement results, the consumption amount of the liquid nitrogen in the fault current limiter 10 of the present invention is greatly reduced. This is useful to greatly reduce the arrangement cost of the fault current limiter.

The present invention is further directed to reduce a decrease of insulation of the cooling liquid and to prevent the occurrence of service loss in normal operation. For the purpose of overcoming these problems, disclosed in Fig. 6 is a test circuit which is designed to reduce heat generation caused by the resistance of the induction coil 4 and eddy current losses in the iron core. The test circuit includes the fault current limiter 10 immersed in the liquid nitrogen in the cooling vessel 6 as shown in Fig. 1, an impedance element in the form of a resistor R located outside the cooling vessel 6 and connected in parallel with the induction coil 4 of fault current limiter 10, a first switch SW1 having a fixed contact connected in series with the induction coil 4 through a resistor 31 of 12Ω and a movable contact connected in series with a power source 30 of alternating current of 60Hz, a second switch SW2 having a fixed contact connected in series with the induction coil 4 through a resistor 32 of 2Ω and a movable contact connected in series with the power source 30, and an ammeter 33 disposed between the power source 30 and the induction coil 4 of the fault current limiter 10. In addition, the first switch SW1 is arranged to be closed in normal operation, while the second switch SW2 is arranged to be opened in the normal operation and to be closed in the occurrence of a short-circuit or thunderbolt.

For simulation tests of the fault current limiter 10, the resistance value of resistor R was changed to measure the current flowing through the test circuit and to measure the replenishment amount of liquid nitrogen into the cooling vessel 6. The measurement results are listed on the following table 1, wherein the replenishment amount of liquid nitrogen is represented as 100% in the case that the resistor R was removed from the test circuit.

Table 1

Test No.	Resistor (Ω)	R/2πfL	SW1 Normal (A)	SW2 Fault (A)	Replenish. Amount (%)
1	0.5	0.34	3.6	19.2	14
2	1.0	0.69	3.6	17.5	30
3	2.0	1.38	3.6	16.0	50
4	3.0	2.10	3.6	15.3	63
5	4.0	2.76	3.6	14.6	68
6	5.0	3.45	3.6	14.3	72
7	Non	--	3.6	13.0	100
8	Non	--	3.6	22.0	--

In Table 1, the character R is the resistance value of resistor R, the character f is the frequency of the alternating current of power source 30, and the character L is the inductance of the induction coil 4. In the simulation tests, the following facts have been confirmed. In the case that the fault current limiter 10 and the resistor R were removed, the current flowing through the test circuit was maintained at a constant value (3.6 A) during normal operation and increased up to 22.0 A in the occurrence of a short-circuit. (see Test No. 8) In the case that the resistor R was removed, the current flowing through the test circuit was maintained at the constant value (3.6 A) during normal operation and increased up to 13.0 A in the occurrence of a short-circuit. (see Test No. 7) From these facts, it has been found that the fault current limiter 10 acts to restrain current of 9A in the occurrence of the short-circuit. When the resistance value of resistor R was decreased, the current limiting effect of the fault current limiter 10 become small, while the replenishment amount of liquid nitrogen become small. This was caused by an increase of shunt current to the resistor R and a decrease of the current flowing through the induction coil of fault current limiter 10.

From the foregoing measurement results, it will be understood that the resistor R connected in parallel with the induction coil 4 is effective to reduce heat generation caused by eddy current losses in the iron core and the resistance of induction coil 4. Accordingly, it is preferable that the resistance value of resistor R is determined taking into consideration the function of the fault current limiter 10 and the replenishment amount of liquid nitrogen. In the test circuit, it was desirable that the resistance value of resistor R was determined to be $R/2\pi fL \leq 3$.

In actual practice of the present invention, the resistor R in the test circuit may be replaced with a condenser C or a coil L_2. The following tables 2 and 3 show measurement results where th capacitance of condenser C or the inductance of coil L_2 was changed to measur the current flowing through the test circuit and t measure the replenishment

amount of liquid nitrogen.

Table 2

Test No.	Resistor (Ω)	$\frac{1}{2\pi fC/2\pi fl}$	SW1 Normal (A)	SW2 Fault (A)	Replenish. Amount (%)
9	2000	0.88	3.6	17.2	42
10	1000	1.77	3.6	15.5	60
11	500	3.53	3.6	14.0	75

Table 3

Test No.	Condenser (μF)	$\frac{2\pi fL_2}{2\pi fL_1}$	SW1 Normal (A)	SW2 Fault (A)	Replenish. Amount (%)
12	3	0.75	3.6	17.4	35
13	5	1.25	3.6	16.5	47
14	10	2.50	3.6	14.9	68

In table 3, the character L_1 is the inductance of the fault current limiter 10, and the character L_2 is the inductance of the coil connected in parallel with the induction coil 4 of fault current limiter 10.

Additionally, it has been found in the simulation tests that heat generation caused by eddy current in the core can be decreased by replacement of the iron core with a core made of a high resistance magnetic material such as ferrite.

The present invention is further directed to avoid fluctuation or decrease of the critical current value of the fault current limiter 10 caused by joule heat of the induction coil. For the purpose of overcoming the problem, disclosed in Fig. 7 is a fault current limiter 10A wherein a cylindrical sleeve 7 made of heat insulating material such as synthetic resin, fiber reinforced plastic or fiber glass is disposed between the induction coil 4 and the cylindrical superconductive body 5. The cylindrical heat insulating sleeve 7 is effective to block joule heat of the induction coil 4 applied to the superconductive body 5 thereby to avoid fluctuation or decrease of the critical current value of the fault current limiter 10.

In Fig. 8 there is illustrated a test circuit of the fault current limiter 10A provided with the cylindrical heat insulating sleeve 7. In the test circuit of Fig. 8, the induction coil 4 of the fault current limiter 10A is connected in series with a power source 40 of alternating current through a resistor 41 at its one end and connected in series with an ammeter 42 at its other end, and a voltmeter 43 is connected in parallel with the induction coil 4 of fault current limiter 10A. For simulation tests of the fault current limiter 10A, the voltage of the power source 40 was adjusted to supply a constant current of 3 A to the fault current limiter 10A for fifteen (15) minutes and increased at a constant speed to measure the critical current value of the superconductive body 5. The measurement results are listed in the following table 4.

Table 4

Test No.	Outer Diameter of Sleeve (mm)	Thickness of Sleeve (mm)	Current Value (A)	Current Value Ratio
1	35	3	9.7	121
2	30	8	10.8	135
3	Non	Non	8.0	100

From the measurement results, it has been confirmed that the critical current value of the superconductive body 5 is increased by the provision of the cylindrical heat insulating sleeve 7.

Claims

1. A superconducting fault current limiter, comprising an induction coil (4) connected in series with an electric power transport line, said coil being arranged in surrounding relationship with a core (3) made of a high resistance magnetic material, said core being carried by a support structure (1) forming a closed magnetic circuit; a superconductive body (5) arranged adjacent to and co-axial with said coil, said superconductive body being made of a

ceramic high-temperature superconducting material; and a cooling d vice (20) arranged to cool said superconducting body; characterised in that said superconducting body (5) surrounds said coil (4) at the outside thereof.

2. A superconducting fault current limiter as claimed in claim 1 wherein said cooling device comprises a cooling container (20) containing only said superconductive body (5) therein and filled with cooling liquid (23) to immerse said superconducting body therein.

3. A superconducting fault current limiter as claimed in claim 1 or claim 2 wherein said superconductive body (5) is in the form of a cylindrical superconductive body coaxial with said induction coil (4).

4. A superconducting fault current limiter as claimed in claim 1 or claim 2 wherein said superconductive body (5) is in the form of a coiled superconductive body coaxial with said induction coil (4).

5. A superconducting fault current limiter as claimed in any of claims 1 to 4 wherein an impedance element (R) is connected in parallel with said induction coil (4) to restrain the flow of current passing through said induction coil (4) on the occurrence of a short-circuit or thunderbolt.

6. A superconducting fault current limiter as claimed in claim 5, wherein said impedance element is one of a resistor (R), a condenser and a coil.

7. A superconducting fault current limiter as claimed in claim 1, wherein a heat insulating material (7) is disposed between said induction coil (4) and said superconductive body (5).

Patentansprüche

1. Supraleitender Fehlerstrombegrenzer, umfassend eine Induktionsspule (4), die mit einer Stromleitung in Serie geschaltet ist, wobei die Spule so angeordnet ist, daß sie einen Kern (3) aus Hochwiderstands-Magnetmaterial umgibt, wobei der Kern von einer Stützstruktur (1) getragen wird, die einen geschlossenen Magnetkreis bildet; einen supraleitenden Körper (5), der angrenzend und koaxial zur Spule angeordnet ist, wobei der supraleitende Körper aus einem bei hoher Temperatur supraleitenden Keramikmaterial besteht; und eine Kühleinrichtung (20), die so angeordnet ist, daß sie den supraleitenden Körper kühlt; dadurch gekennzeichnet, daß der supraleitende Körper (5) die Spule (4) an ihrer Außenseite umgibt.

2. Supraleitender Fehlerstrombegrenzer nach Anspruch 1, worin die Kühleinrichtung einen Kühlbehälter (20) umfaßt, der nur den supraleitenden Körper (5) darin enthält und mit Kühlflüssigkeit (23) gefüllt ist, um den supraleitenden Körper darin einzutauchen.

3. Supraleitender Fehlerstrombegrenzer nach Anspruch 1 oder 2, worin der supraleitende Körper (5) die Form eines zylindrischen supraleitenden Körpers hat, der zur Induktionsspule (4) koaxial ist.

4. Supraleitender Fehlerstrombegrenzer nach Anspruch 1 oder 2, worin der supraleitende Körper (5) die Form eines gewundenen supraleitenden Körpers aufweist, der zur Induktionsspule (4) koaxial ist.

5. Supraleitender Fehlerstrombegrenzer nach einem der Ansprüche 1 bis 4, worin ein Impedanzelement (R) zur Induktionsspule (4) parallel geschaltet ist, um den beim Auftreten eines Kurzschlusses oder eines Blitzschlags durch die Induktionsspule (4) hindurchgehenden Stromfluß einzudämmen.

6. Supraleitender Fehlerstrombegrenzer nach Anspruch 5, worin das Impedanzelement ein Widerstand (R), ein Kondensator oder eine Spule ist.

7. Supraleitender Fehlerstrombegrenzer nach Anspruch 1, worin ein wärmeisolierendes Material (7) zwischen der Induktionsspule (4) und dem supraleitenden Körper (5) angeordnet ist.

Revendications

1. Limiteur de courant de défaut à supraconduction, comprenant une bobine d'induction (4) reliée en série avec une

ligne de transport d'énergie électrique, ladite bobine étant agencée en relation environnante avec un noyau (3) réalisé en un mat´riau magn´tique de résistance élevée, ledit noyau étant port´ par une structur de support (1) formant un circuit magnétiqu fermé ; un corps supraconducteur (5) agencé adjacent à ladite bobine et coaxial à celle-ci, ledit corps supraconducteur étant réalisé en un matériau supraconducteur de céramique à température élevée ; et un dispositif de refroidissement (20) agencé pour refroidir ledit corps supraconducteur ; caractérisé en ce que ledit corps supraconducteur (5) entoure ladite bobine (4) à l'extérieur de celle-ci.

2. Limiteur de courant de défaut à supraconduction comme revendiqué en revendication 1 dans lequel le dispositif de refroidissement précité comprend un récipient de refroidissement (20) contenant seulement le corps supraconducteur précité (5) dans celui-ci et rempli d'un liquide de refroidissement (23) pour immerger dans celui-ci ledit corps supraconducteur.

3. Limiteur de courant de défaut à supraconduction comme revendiqué en revendication 1 ou revendication 2 dans lequel le corps supraconducteur précité (5) est sous la forme d'un corps supraconducteur cylindrique coaxial à la bobine d'induction précitée (4).

4. Limiteur de courant de défaut à supraconduction comme revendiqué en revendication 1 ou revendication 2 dans lequel le corps supraconducteur précité (5) est sous la forme d'un corps supraconducteur bobiné coaxial à la bobine d'induction précitée (4).

5. Limiteur de courant de défaut à supraconduction comme revendiqué dans l'une quelconque des revendications 1 à 4 dans lequel un élément d'impédance (R) est relié en parallèle à la bobine d'induction précitée (4) pour restreindre l'écoulement de courant passant à travers la bobine d'induction (4) sur l'apparition d'un court-circuit ou de la foudre.

6. Limiteur de courant de défaut à supraconduction comme revendiqué en revendication 5, dans lequel l'élément d'impédance précité est une résistance (R), un condensateur ou une bobine.

7. Limiteur de courant de défaut à supraconduction comme revendiqué en revendication 1, dans lequel un matériau d'isolation thermique (7) est disposé entre la bobine d'induction précitée (4) et le corps supraconducteur précité (5).

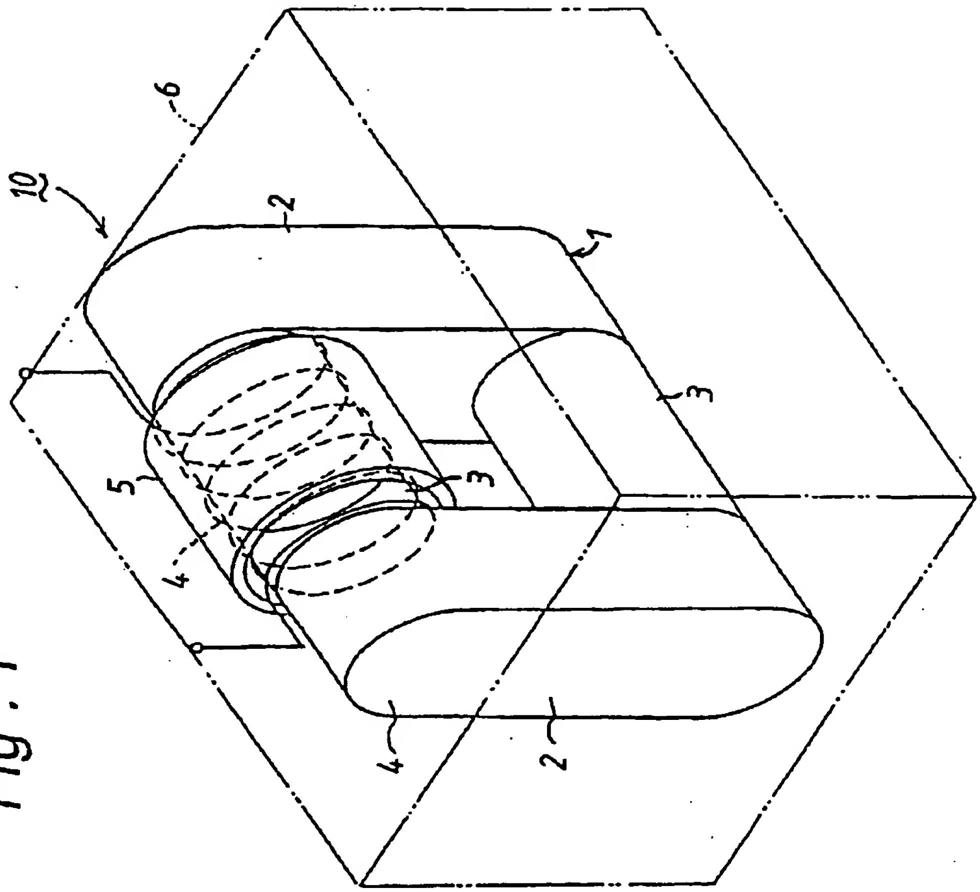

Fig . 1

Fig . 2

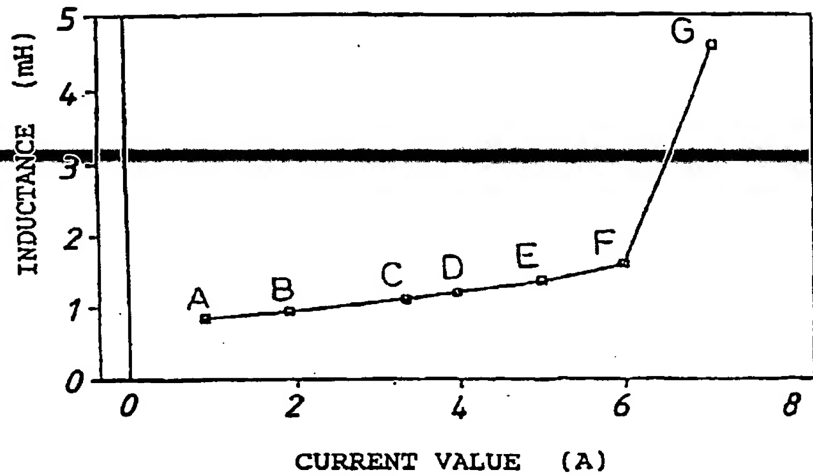

Fig . 3

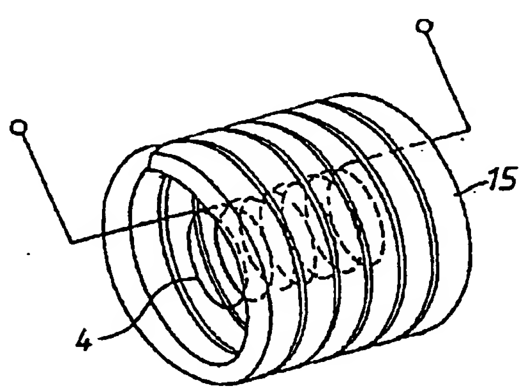

Fig . 4

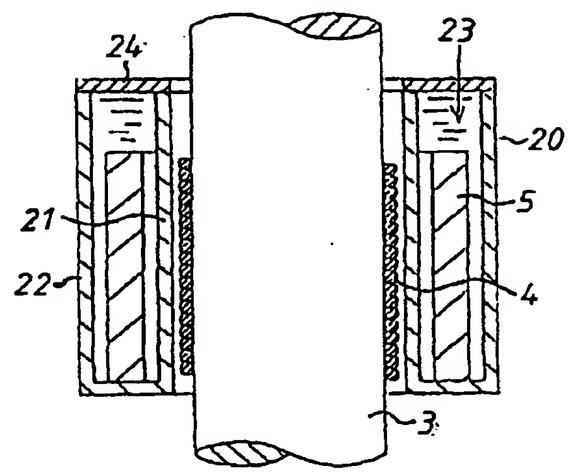

Fig . 5

CONSUMPTION AMOUNT OF LIQUID NITROGEN

	CONVENTIONAL FAULT CURRENT LIMITER	FAULT CURRENT LIMITER OF PRESENT INVENTION
3A BEFORE TRANSITION	60g/min	30g/min
10A AFTER TRANSITION	180g/min	50g/min

Fig . 6

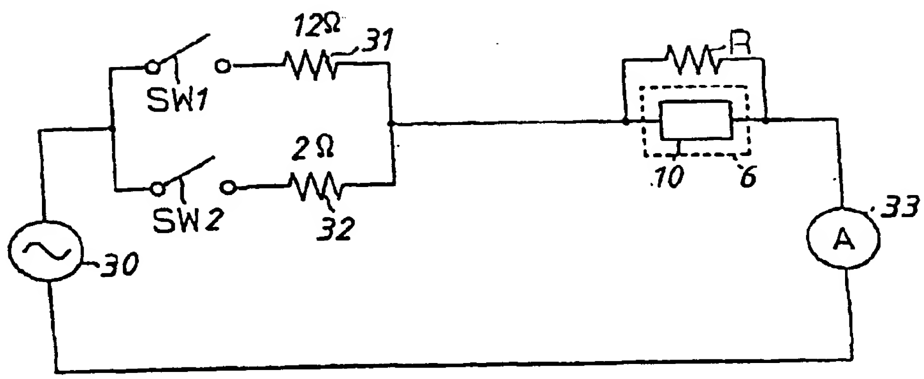

Fig . 7

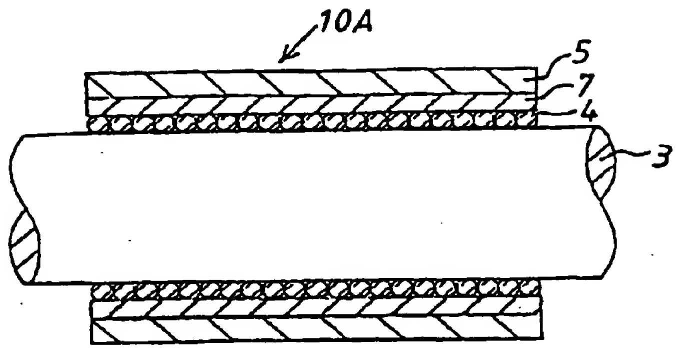

Fig . 8